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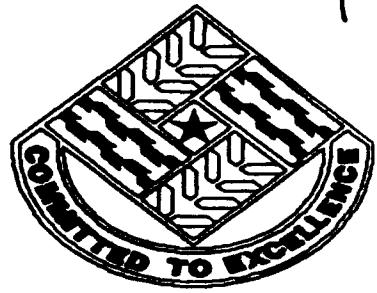
## STUDYING THE COST EFFECTS OF THE SHRINKING INDUSTRIAL BASE

Downsizing the Army has the effect of reducing the level of involvement of corporations in the defense contracting environment; thus, the size of the industrial base decreases. The paper analyzes the cost impacts of the shrinking industrial base with a discussion of the cause/effect issues involved in relating industrial base size to cost. In addition, the paper studies trends in the size of the industrial base over the past several years. Corporate data is used to determine the amount of assets devoted to a particular defense industry over time. Emphasis will be placed on tracked vehicles. The goal is to advance the state of cost analysis by anticipating cost changes on a macro level.

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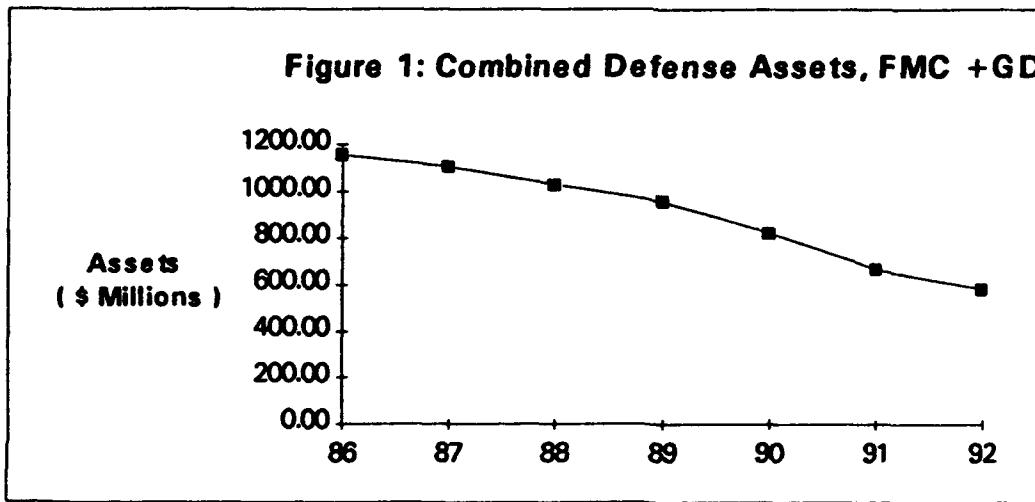
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### **INTRODUCTION**

For cost analysts, one of the most puzzling aspects of the downsizing of the military is the effect of changes in the size of the defense industrial base on cost. It is common knowledge that the downsizing is having an effect on unit vehicle cost, but there is no existing conceptual framework that can be used to predict such an effect.

An example of a diminishing industrial base segment is shown in Fig. 1. Here we see the combined defense-related assets of two major defense contractors, FMC and General Dynamics, over the past several years. These figures are taken from COMPUSTAT, a data system for financial analysis that includes financial and market data for individual corporations, business segments, and industry composites.

**Figure 1: Combined Defense Assets, FMC + GD**



A possible methodology that could be used in determining the effect of the shrinking industrial base on unit cost would be to simply take actual data and try to find a relationship. Some measure of the size of the industrial base would be necessary, as would be some measure of unit cost. Data on the size of the industrial base over the past several years would be collected, as would data on unit costs of various vehicle systems. A number of mathematical techniques could be used to seek a relationship between the two factors. Once a relationship between industrial base size and unit cost has been developed, it could be used to predict how further shrinkage of the industrial base will affect unit cost.

There are two problems with this approach. The first problem is that a macro-level approach such as this is not responsive to changes in the underlying conditions that are affecting cost. For example, if the configuration of a vehicle is modified significantly, the entire model has to be thrown out and a new one developed.

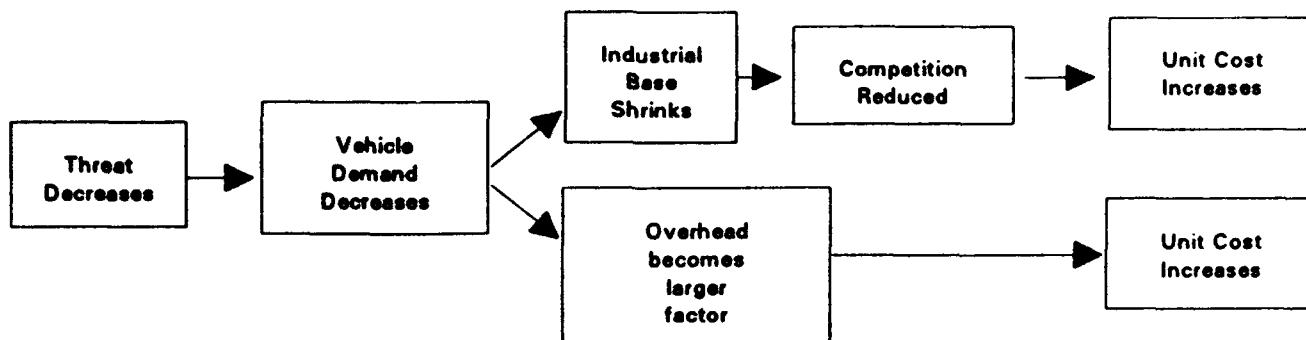
The second problem is that this approach does not isolate the cost effects of changes in the industrial base. There are many other factors affecting cost, and all these factors interact to produce the final cost value that the analyst ultimately sees when data is collected. Industrial base changes only account for a portion of the total change in unit vehicle cost.

Let's take a closer look at some of the factors that affect unit cost. When the military lowers its required number of vehicles, fewer new vehicles need to be produced. Thus there is less business for defense contractors. This conceivably could cause some contractors to take their business elsewhere or reduce the amount of their defense-related activities. A reduction in the number of defense contractors willing to produce a given vehicle system could result in a less competitive bidding environment. This in turn could increase production costs.

In addition, when the quantity of vehicles produced declines, overhead costs loom larger. Overhead costs are allocated over a smaller number of vehicles, thus increasing vehicle unit cost.

Thus we see that reducing the quantity of vehicles produced could conceivably increase unit vehicle costs for two distinct reasons: reduced competition (due to the smaller industrial base) and increased overhead costs per unit (see Fig.2: Cause and Effect Diagram). Since both reduced competition and increased overhead affect unit cost, any attempt to find a mathematical relationship between the size of the industrial base and unit cost will be errant due to the affects of the increased overhead costs per unit. The various factors affecting cost are intertwined in such a way as to make it theoretically unsound to attempt to directly relate any of these factors individually to unit vehicle cost without considering the other effects.

**Figure 2 : Cause and Effect Diagram**



In order to study the effects of changes in the industrial base on cost, we are inevitably drawn toward studying the effects of numerous other factors on cost. This is because the cost data we are presented represents the sum effect of the interaction of countless factors affecting cost. In fantasyland, an experiment could be designed to test the effects of each factor on unit vehicle cost, holding all other factors constant while varying the one factor. Of course, this is not possible in the real world environment-we cannot ask the Department of Defense to, for example, refrain from changing the configuration of a vehicle system solely for the purpose of testing cost effects.

## A MODEL

A different approach is to devise a mathematical model that incorporates the major factors affecting vehicle unit cost, and also includes a factor that accounts for the effects of changes in the defense industrial base. If the effects of the non-industrial base factors are known, and the resultant total cost is known from cost data, the effect of the industrial base can be solved for algebraically. In this sense the effect of the shrinkage of the industrial base is found by "backing into" it. This industrial base factor will be changing over time. Trends in the industrial base factor can then be found and used to predict future industrial base factors, which can be used to predict costs.

What we are discussing is an equation that would relate the major factors that affect cost to each other. This model would not take the place of other cost analysis techniques, but rather would act as an overall conceptual framework from which to coordinate them. The model would not stand alone because other cost analyses must be initially be performed in order to develop some of the factors necessary in the model, as we shall see.

**Figure 3: Model Levels**

	<b>Ease of Use</b>	<b>Responsiveness</b>
<b>Macro-Level Model</b>	HIGH	LOW
<b>Mid-Level Model</b>	MEDIUM	MEDIUM
<b>Micro-Level Model</b>	LOW	HIGH

There are various levels of model detail (see Fig.3). Micro-level models are the most complex. As a cost model becomes more complicated by incorporating more factors, it becomes more sensitive to changes in those factors. This comes at the price of increasing the data requirements of the model. A very complicated model may also become difficult to run. At the other extreme, a macro-level model is easy to use and has low data requirements, but it lacks responsiveness to changes in the underlying factors that affect cost. What is sought is a happy medium; a model that will be sensitive to changes in the major factors affecting cost without becoming so complex as to make it unusable in practical applications.

What factors do we want to include in this cost model? Certainly we want to have provisions for the two factors that increased unit cost in Fig.2, namely industrial base shrinkage (or competition reduction) and overhead costs.

We can write a simple, "starter" cost model as follows:

$$\text{Cost} = \text{Previous Cost} * \text{Industrial base factor} \quad (1)$$

where the Industrial Base Factor represents a multiplier that would account for changes in the industrial base. "Previous Cost" would be either an estimated value or an actual value of the cost of the same system in the past. Thus we see that the model being considered would be one that takes a past cost value and updates it based on one or more changing factors.

## ACCOUNTING FOR OVERHEAD

How can we make our model sensitive to overhead cost changes? When we ask this question we begin to get into the area of fixed and variable (with respect to quantity) costs. Intuitively, it does not seem to make sense to simply attach another factor to equation (1) above and call it the "affect of overhead changes" factor. A more reasonable approach would be to start with the basic form of a fixed/variable cost equation:

$$\text{Cost} = \text{Fixed Cost} + (\text{Variable Cost} * \text{Quantity}) \quad (2)$$

or

$$\text{Cost} = F + (V*Q) \quad (3)$$

What equation (3) does is express the "Previous Cost" in equation (1) in a more detailed format. We can substitute the right half of equation (3) for the "Previous Cost" term in equation (1):

$$\text{Cost} = \text{Previous Cost} * \text{Industrial base factor} \quad (1)$$

$$\text{Cost} = \{F + (V*Q)\} * \text{Industrial base factor} \quad (4)$$

or

$$\text{Cost} = \{F + (V*Q)\} * I \quad (5)$$

Keep in mind that the Industrial base factor  $I$  does not represent a measure of the size of the industrial base, rather, it represents a multiplier that adjusts the rest of the equation for the effects of the industrial base changes, whatever they may be.

Before we progress with the inclusion of other factors to account for other cost drivers, a discussion of the practical usage of equation (5) is in order. Suppose the following information is known about a previous production lot of a particular system (call this lot 1):

Previous fixed cost ( $F_1$ )

Previous variable cost ( $V_1$ )

Previous quantity produced ( $Q_1$ )

and suppose the following information is known about a current scheduled production of the same system (call this lot 2):

Current fixed cost ( $F_2$ )

Current variable cost ( $V_2$ )

Current quantity produced ( $Q_2$ )

If we assume that the industrial base accounts for all the cost changes from the previous lot to the current lot, we can use equation (5) to solve for the industrial base factor I.

$$\text{Cost} = \{F + (V*Q)\} * I \quad (5)$$

By definition, the industrial base factor I is the adjustment factor that accounts for the effects of changes in the industrial base. Since we are assuming in this case that all cost changes are due to the industrial base changes, we can state that

$$\{F_1 + (V_1*Q_1)\} * I = \{F_2 + (V_2*Q_2)\} \quad (6)$$

Knowing (or at least estimating) all variables except I, we can solve for I. In this fashion we could get a handle on the effect the industrial base is having on cost.

The industrial base factor I as it is used in equation (6) actually is specific to the two lots being examined (lots 1 and 2, previous and current). We could call the I used in equation (6)  $I_{12}$  to show that it converts lot 1 cost to lot 2 cost.

To continue to monitor the effect of the industrial base, the same procedure above would be applied to the third production lot. Note that in order for the industrial base factor I to have any meaning, it must refer to the same base conditions. Thus for the third production lot studied, the equation used to solve for  $I_{13}$  would be

$$\{F_1 + (V_1*Q_1)\} * I_{13} = \{F_3 + (V_3*Q_3)\} \quad (7)$$

If this pattern of solving for the industrial base factor is continued over a number of lots, eventually we will have a series of values for I ( $I_{12}$ ,  $I_{13}$ ,  $I_{14}$ ,  $I_{15}$ , etc.) that can be examined for trends and thus used to predict future costs.

## CONFIGURATION CHANGE

Having had a look at the eventual practical usage of the model, we are in a better position to flesh out the model with more factors. Recall that the general equation for the model was as follows:

$$\text{Cost} = \{F + (V*Q)\} * I \quad (5)$$

where "Cost" represents the cost of the current lot and  $\{F + (V*Q)\}$  represents the cost of the previous, or base lot. We have seen that in order to use the equation to find the industrial base factor, we needed to assume that changes in the industrial base accounted for all the change in cost from one lot to the next. Of course this is unlikely. One factor that could very likely come into play is configuration change. Suppose we were to add a factor, call it C, to our equation to account for the cost effects of a particular change in configuration.

$$\text{Cost} = \{F + (V \cdot Q)\} \cdot I \cdot C \quad (8)$$

In equation (8) the factors I and C are used to adjust a previous production lot's cost (represented by  $F + (V \cdot Q)$ ) for the effects of industrial base changes and configuration changes.

A greater deal of accuracy can be obtained by splintering the configuration factor C into two factors, one that would apply to fixed costs and one that would apply to variable costs. The equation would look like this:

$$\text{Cost} = \{F \cdot C_f + (V \cdot C_v \cdot Q)\} \cdot I \quad (9)$$

where  $C_f$  is a multiplier that accounts for the effects of configuration change on fixed cost, and  $C_v$  is a multiplier that accounts for the effects of configuration change on variable cost. Thus the model makes provisions for the possibility that a change in configuration could have a different level of impact upon fixed costs than variable costs.

We have seen previously that in order to use the model to solve for the value of the industrial base factor I, we need to know the values of all the other variables in the equation, both for the previous (or base) lot and the current lot. Since we have added the configuration change factors to the equation, we need to find values for these factors in order to be able to solve for I. We are now required to estimate the effects of configuration change on cost in order to determine the appropriate values for  $C_f$  and  $C_v$ . This would most likely be accomplished by an independent study, perhaps using expert opinion.

The equation that would be used to solve for the industrial base factor I would then be

$$\text{Cost of previous lot} \cdot I = \text{Cost of current lot}$$

$$\{F_1 \cdot C_{f1} + (V_1 \cdot C_{v1} \cdot Q_1)\} \cdot I = \{F_2 \cdot C_{f2} + (V_2 \cdot C_{v2} \cdot Q_2)\}$$

(10)

where the subscripts ending with a 1 or 2 indicate whether the variable/factor applies to production lot 1 (previous lot) or 2 (current lot).

Since production lot 1 (previous lot) is the basis for determining later configuration changes, by definition the value of the configuration change factors  $C_{f1}$  and  $C_{v1}$  equals 1. All other variables in the equation would have to be determined by either historical data or independent estimates, save for the industrial base factor which could be determined mathematically given the other information.

## LEARNING CURVE EFFECT

The model can be altered to account for the effects of learning. Learning will affect the variable cost per vehicle  $V$ . Instead of being constant,  $V$  will change with each consecutive unit produced (if learning is in fact evident). Recall equation (9):

$$\text{Cost} = \{F * C_f + (V * C_v * Q)\} * I \quad (9)$$

The total variable cost is the product of  $V$  and  $Q$  (the variable cost per vehicle multiplied by the quantity of vehicles). In learning terms, the cost due to variable costs could also be expressed as

$$\text{total variable cost} = \sum_{k=1}^Q (V * k^B) \quad (11)$$

where

$V$  = cost of the first unit produced in the lot

$B$  = learning curve exponent

$k$  = a counter variable counting from one to the quantity  
of vehicles in the lot ( $Q$ )

$Q$  = quantity of vehicles in the lot

Equation (11) is simply the sum the individual production costs of every unit in the lot. The cost of each unit is determined by multiplying the cost of the first unit by the factor  $k^B$ , which reduces the cost to account for the learning that has taken place.

We can substitute the right half of equation (11) for  $V * Q$  in equation (9) because they both equal the total variable cost.

We now have

$$\text{Cost} = [F * C_f + \{C_v * \sum_{k=1}^Q (V * k^B)\}] * I \quad (12)$$

$V$  now represents the variable cost of the first unit produced. This equation shows how total cost can be determined based upon variables relating to a previous (base) production lot, and the industrial base factor  $I$ . To avoid an avalanche of subscripts, let us rename the portion of equation (12) enclosed in brackets  $[X]$ .  $[X_1]$  will apply to lot 1 (the base lot), and  $[X_2]$  will apply to lot 2, the current lot. First, we rewrite equation (12):

$$\text{Cost} = [X] * I$$

$$[X] * I = \text{Cost}$$

**Previous lot cost \* I = Current lot cost**

$$[ X_1 ] * I = [ X_2 ] \quad (13)$$

Knowing or estimating all of the variables in  $[ X_1 ]$  and  $[ X_2 ]$ , we can then solve for the industrial base factor  $I$ . If this is done for successive lots, eventually we can look for trends in the industrial base multiplier. These trends can be used to predict future values of the industrial base factor, which in turn can be used to predict the cost effects of changes in the industrial base.

## PRACTICAL USES AND APPLICATIONS

The model can be used a number of ways. It provides a general framework from which to analyze vehicle costs that are impacted by industrial base changes, configuration changes, overhead allocation considerations, and learning. Thus the potential applications of the model are many.

The model can be used to determine the effects of the industrial base on cost. This is accomplished by modeling the major factors affecting cost, keeping track of these factors and the resultant costs over time, and then mathematically backing into the effect of industrial base changes. This industrial base effect is measured by an industrial base factor. Once the effects of the industrial base have been studied over time, trends can be found. These trends can be used to predict future industrial base factors which in turn can be used to predict costs. Depending upon the availability of the necessary historical information, it is also possible that past data could be studied in order to determine the trend in industrial base effects, thus expediting the process.

In order to get the model up and running, a number of input parameters need to be determined. These are the learning curve exponent, the configuration change multipliers, and the fixed and variable costs from a previous production lot. These factors would have to be determined by historical data and/or independent study.

The model shows on a macro level the interrelationship of the major factors affecting cost. The framework from which to begin studying the cost effects of the industrial base has been created. The individual factors and data must be provided by the cost analyst.

## POSTSCRIPT ON MEASURING THE SIZE OF THE INDUSTRIAL BASE

While the model developed in this paper provides a means of studying the *effects* of the changing industrial base, it is still advantageous to keep track of the size of the industrial base itself, for purposes of verification. It is also possible that a statistical relationship could be found between the size of the industrial base and the industrial base factor  $I$  discussed previously. For these reasons it is desirable to have some means of measuring the size of the defense industrial base.

In Fig.1, the size of the industrial base was measured in terms of the total defense assets of two major producers of ground vehicles. Total assets is not the only financial statistic that could be used to measure the size of the industrial base; arguments could be made for using sales, number of employees, net assets, and others.

The data for Fig.1 was taken from the COMPUSTAT data system for financial analysis. COMPUSTAT is a quite complex system with many applications and specialized reports. For the data in Fig. 1, a historical business segment report was run for FMC and General Dynamics. This report showed the portion of the companies' total assets that were devoted to defense during the last several years.

A problem with the COMPUSTAT system is that it is sometimes difficult to separate defense statistics from commercial industry statistics. For example, COMPUSTAT does not distinguish between the defense automotive and commercial automotive business segments. An individual company may report its statistics separately for defense production and commercial production, but there is no guarantee that all companies involved in defense will isolate defense statistics this way. For the data in Fig.1, this was not an issue because the data relates to tracked vehicles which are obviously used for defense.